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Overview of the Holocene History, Architecture, and Structural Components of Tague Reef and Lagoon

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INTRODUCTION

This paper presents a synopsis of the data from two coring programs that investigated Tague Reef off the northeast coast of St. Croix. This 7.8-km-long bank-barrier reef, located between Pull Point to the west and Lamb Point to the east (Fig. 1), is situated on the St. Croix insular platform, over 2 km from the shelf edge. The bank-barrier reef (Adey, 1975) is one geologic type belonging to the basic tripartite reef system of St. Croix (Adey and Burke, 1976; Adey, 1978) that also includes fringing and shelf-edge reefs (Adey et al., 1977b).

Setting

The shoreline behind Tague Reef is characterized by arcuate bays with skeletal sand beaches and rocky headlands. At some locations, such as in portions of Boiler Bay, the sand is cemented to form beach rock. Colluvial deposits occur behind most beaches and flank headlands. Headlands are formed by highly indurated, deep marine sediments of the Cretaceous Caledonia Formation.

Tague Reef has an essentially linear east-west trend that does not follow the promontories of the adjacent shoreline. As a result, the distance between the reef and shore is highly variable, ranging from a maximum of 0.9 km at its western end, to nothing where it fringes against the shore at Lamb Point. The reef crest is continuous at a depth of generally less than 0.5 m (mean low water) from Solitude Bay in the west to Cottongarden Bay in the east. West of Solitude Bay the reef becomes segmented into a sublinear series of patch reefs; the westernmost segment forms a fringing reef around Sand Cay. East of Cottongarden Bay the reef crest is generally deeper and wider, and the reef is broken into broad patch reefs. A few deep (approximately 2.5 m), tortuous sand channels pass through the crest at Boiler Bay. The crest shoals at the eastern end of Boiler Bay forming a broad, shallow fringing reef.

Lagoon depths range from a maximum of approximately 8 m west of Tague Point to 1 m in the backreef at both the eastern and western ends of the reef tract. Seaward of the main barrier, Buck Island Channel deepens to the east from a shallow depth of 8 m north of Sand Cay to 20 m north of Boiler Bay. Channel Rock, at the eastern end of Buck Island Channel, defines the crest of another elongate reef that parallels Tague reef and shoals to a depth of less than 2 m (Fig. 1).

The zonation pattern of the reef community generally parallels the reef trend. The lagoon is characterized by seagrasses and sediment-dwelling organisms dominated by molluscs and echinoderms. Calcareous algae are, for the most part, dominated by *Penicillus* sp. and a variety of *Halimeda* spp. The abrupt transition from the lagoon to the backreef is marked by scattered corals (particularly *Montastrea annularis* and *Porites),* gorgonians, and a variety of fleshy algae. The reef crest is distinguished by a diverse, mixed coral community including *Acropora palmata* and *Porites asteroides,* with the seaward portion occupied largely by *Acropora palmata* and the hydrozoan *Millepora* sp. The shallow forereef typically supports stands of *Acropora palmata,* which give way in the deeper forereef to *P. porites, A. cervicornis, M. annularis,* and *Diploria* spp. These various living corals are not the primary structural components of the reef crest; sediment and rubble cover more area and volume than do the living corals. Additional detailed information about the character of Tague reef are presented in Muller and Gerhard (1974), Dahl *et at,* and Adey *et* at. (1977a). The relationship of Caribbean reef framework components to environmental factors of shelf depth, energy, and water quality are diagrammatically summarized in Adey and Burke (1977).

METHODS

Cores were collected from the reef crest with a portable rotary drill mounted on a platform above the reef. A submersible drill was used to obtain cores from deeper-water sites in the lagoon and on the forereef. Notes were made on the drilling character every 1.5 m, with emphasis on the depth at which hard substrates were contacted, the

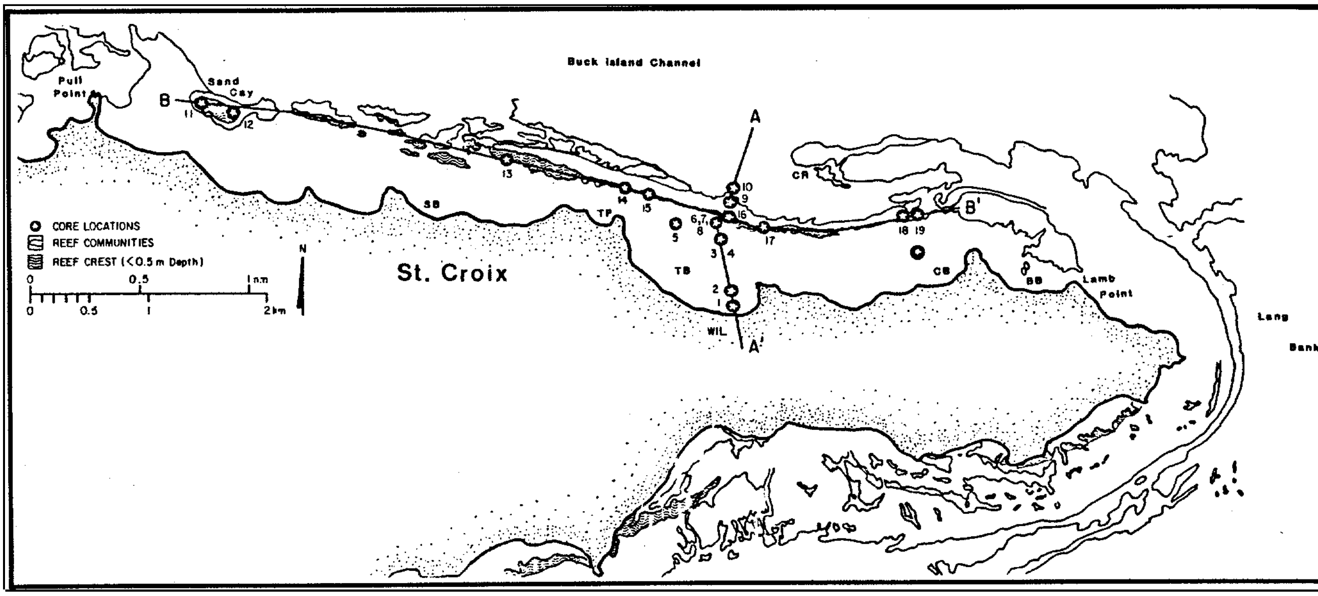

***Figure 1**. Location map of Tague Reef, St. Croix, U.S.V.I. with core locations numbered. Line A-A' connects the cores taken in a transect from the lagoon to the forereef. Line B-B' connects the cores taken along the reef crest. Place name abbreviations: BB = Boiler Bay, CB = Cottongarden Bay, CR = Channel Rock, SB = Solitude Bay, TB = Tague Bay, TP = Tague Point, and WIL = West Indies Lab.*

rates of drilling, and the ease of penetration. Sediment thickness was determined in some instances by probing for hard substrate with a steel rod.

Each core was examined macroscopically to identify the major components (e.g., coral species, sediment, cements). Thin sections were made of 51 samples, to confirm composition and to assess diagenesis. Radiocarbon dating of 12 samples was used to determine the age of the reef, accretion rates, and the timing and sequence of reef development. Additional samples were examined by X-ray diffraction to help define the boundary between Holocene and pre-Holocene based on the presence of low-magnesium calcite.

RESULTS

Fourteen cores were recovered from the locations along the reef crest. Nine additional cores were taken at six different locations along a transect from the lagoon to the forereef (Fig. 1). Another four cores were taken from a patch reef in Cottongarden Bay and one core was taken in Tague Bay.

The major components recovered in the cores were corals (Figs. 2 and 3). Recovery of sediment was poor, resulting in total recoveries of less than 30%. Recovery was generally greater in the upper, coral-rich portions of the reef. The lower portions of the cores consisted mostly of sand and rubble with only a few corals. The most common corals recovered were *Acropora palmata* and *Montastrea annularis*. Lesser amounts of *Diploria* sp., *Porites* sp., the hydrozoan *Millepora* sp., and crustose coralline algae were retrieved. In cores collected from the backreef, the sequence of reef development began with head corals that locally colonized the pre-Holocene surface (Fig. 2). *Acropora palmata* then replaced the head corals and further reef development consisted of alternating head coral and A. *palmata* growth as the reef prograded seaward. The reef was capped by a mixed reef community including *A. palmata* and *M. annularis*. In contrast, cores taken at the reef crest reveal that reef development usually began with either A. *palmata* or head corals colonizing sediment bottoms as opposed to hard substrate. After A. *palmata* became established at a particular site, it was usually overgrown by a mixed coral community that included *Millepora* sp. and coralline algae which presently cap the outer edge of the reef crest.

Along the reef crest, pre-Holocene limestone was recovered in three cores, and the pre-Holocene contact was located with a probe in another core hole after collapse of sand into its base. The pre-Holocene contact was established in six cores along the reef transect; in two cores, the underlying unit was colluvium and in four others limestone. The colluvium contained angular clasts from the Cretaceous Caledonia Formation. The pre-Holocene age of the limestone was inferred from its low-magnesium calcite mineralogy.

A 4-m high bench was found 180 m behind the reef crest in the pre-Holocene strata beneath Tague Bay (Fig. 2). Cores taken along transect B-B' indicate that the pre-Holocene contact dips to the east (Fig. 3). Depth to the pre-Holocene limestone along the reef crest ranged from 8.1 m at Sand Cay (core location 12) to 13.8 m off Tague

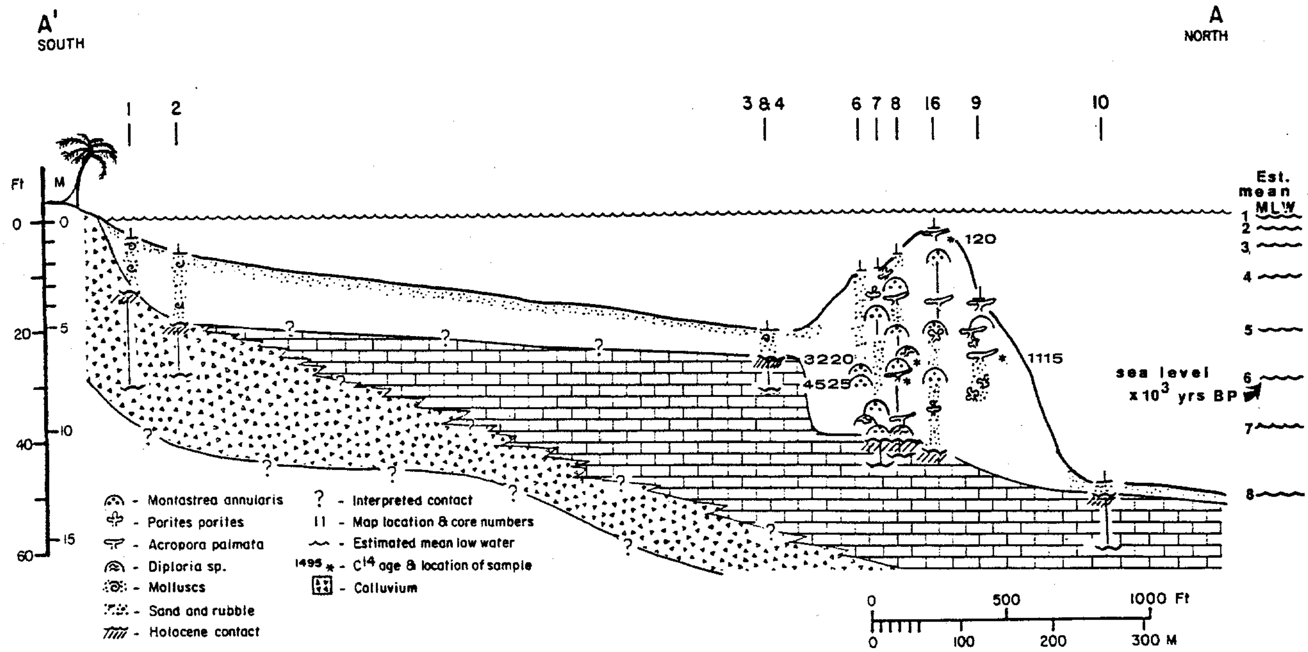

Figure 2. Diagrammatic section of the lagoon to forereef transect (A-A') showing the location of cores, the major components found in the cores, the Holocene-pre-Holocene contact, and radiocarbon dates. Pre-Holocene limestones are shown by the "brick" pattern in this and Figure 3. The position of Neumann s Holocene sea level (Adey, 1975) is indicated on the right margin in thousand-year increments. Note that reef development is seaward of the four-meter-high bench.

Bay (core location 17). At Sand Cay, the pre-Holocene limestone was overlain by silty clays of unknown age. Depth of the pre-Holocene contact across the reef transect ranged from 4.1 m in the lagoon (core location 1) to 15.5 m on the forereef (core location 10).

Radiocarbon dates ranged from modern to 6,135 ybp ± 80 years. The oldest dates were from A. *palmata* from core location 17 off Tague Bay. Radiocarbon dates from cores along the reef crest (Fig. 3) revealed that massive framework components of the reef initiated their growth at different times. Accretion rates ranged from 1.1 m/1,000 yr to 5.1 m/1,000 yr. The highest rate of accretion occurred off Tague Bay (core location 17) in the A. *palmata* facies. The slowest rate of accretion was recorded in the core from Sand Cay (core location 11) in the mixed coral facies.

Macroscopic examination of the cores showed that there was volumetrically little cementation. Thin-section analysis revealed that cements were limited to thin, high-magnesium calcite crusts and infilled borings. Epitaxial overgrowths of aragonite were present in minor amounts as intraskeletal cement within corals.

DISCUSSION AND CONCLUSIONS

Core recovered shows that massive framework components are scattered and do not bind together the reef structure as has been commonly reported. Sediment is the most common component of Tague Reef. The framework components appear to act as baffles that decrease wave and current energy and thus trap sediment around them, helping to stabilize the reef structure. The normal succession of reef communities from deep to shallow water is head corals overlain by A. palmata and then mixed corals.

The staggered dates for reef development (Fig. 3) suggest that Tague Reef began as a series of isolated patches that formed at different times. The patch reefs grew laterally as sediment and debris infilled between reefs and were colonized over time. Cores from the reef crest show that the importance of sediment in the reef fabric increases to both the east and west from Tague Bay (core locations 15, 16, and 17). This suggests that the earliest patch reefs may have initiated at a central location in Tague Bay. The thickest zone of massive framework components occurs in the central portion of the reef, which further supports the idea of a central area of early reef development.

The initiation of reef development seaward of the 4-m bench in Tague Bay (Fig. 2) supports the hypothesis of Ogden (1974) that bank-barrier reefs grow on wave-cut terraces. However, the reef did not initiate on the topographically highest point (top of the bench), but rather on the terrace in front of it, suggesting that the sublinear east-west trend of the reef may be controlled by the location of the antecedent 4-m bench.

The location of the present reef crest seaward of the site of initial reef development is the result of seaward reef progradation (Fig. 2). This is well-documented by radiocarbon dates; where more than one date was obtained

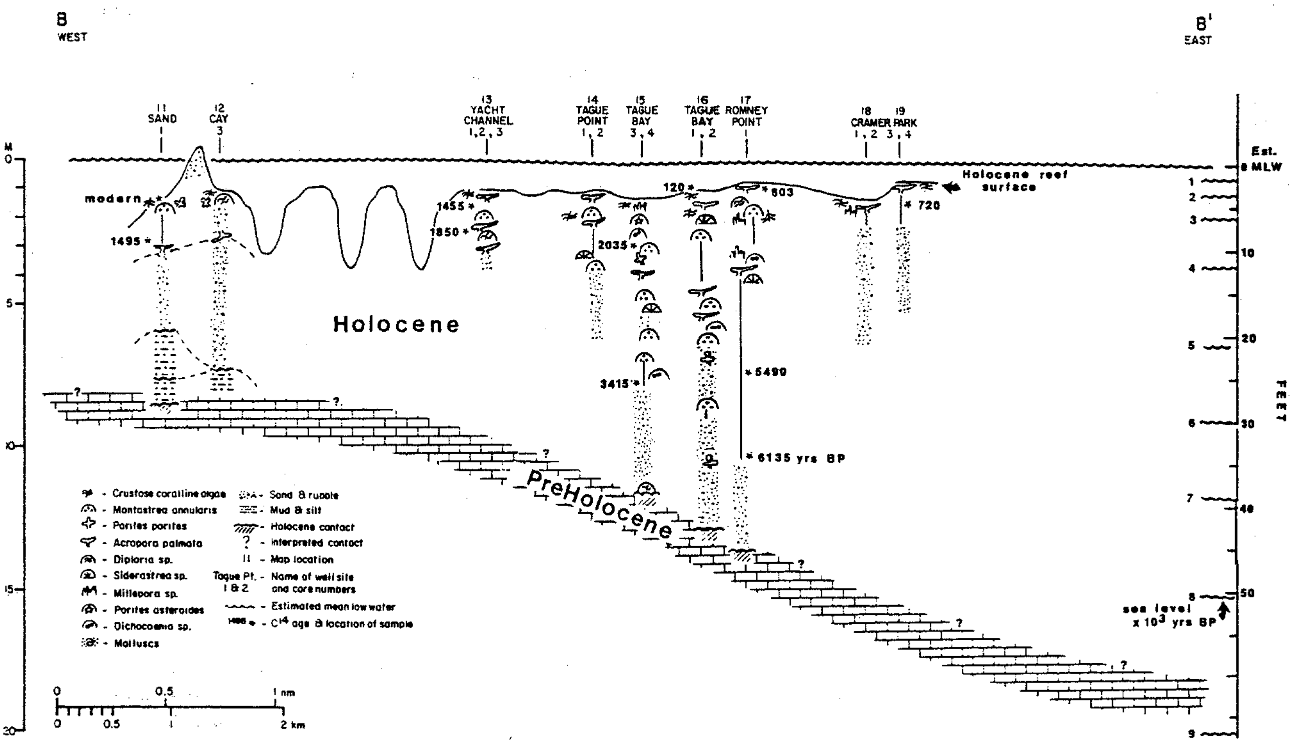

***Figure 3**. Diagrammatic section along the reef crest (B-B') showing the location of cores, the major components found in the cores, the Holocene-pre-Holocene contact, and radiocarbon dates. The position of Neumann's Holocene sea level (Adey, 1975) is indicated on the right margin in thousand-year increments.*

at a particular depth, the age of the more seaward core was younger. This finding, along with several others already discussed, emphasizes the importance of taking core samples along the trend of the reef as well as in transects normal to reef crest.

The central initiation of Tague Reef suggests that there may have been some optimal position on the insular shelf for reefs to become established within the context of Holocene sea level rise, the easterly dip in the pre-Holocene contact, and local water quality conditions. As sea level rose gradually over the pre-Holocene surface of Lang Bank and filled Buck Island Channel from the east, water quality would have improved slowly from that of a turbid lagoonal environment to a clear, open-water environment once the west end of Buck Island Channel was inundated. This improvement in water quality would promote reef development. Considering Neumann's sea level curve (Adey, 1975), the 8 m pre-Holocene contact at Sand Cay (core location 11), and the present maximum depth of 9.5 m at the western end of Buck Island Channel, sea level would not have inundated Buck Island Channel until about 6100 ybp. This age is coincident with the oldest date (6135 ybp) obtained in the cores, from *Acropora palmata* which grows only in areas of good water quality. Development at the eastern end of Tague Reef was apparently controlled by poor water quality and excessive water depth. The slow reef development at the shallower western end of Tague Reef may be a function of heavy sediment loads associated with the flushing of Buck Island Channel and the early establishment of high rates of carbonate production to the east (upcurrent). This model of reef development will be discussed in more detail in a forthcoming paper by the authors.

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